The Sixth International Microgravity Combustion Workshop

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NASA's Evolving Microgravity Combustion Science Program

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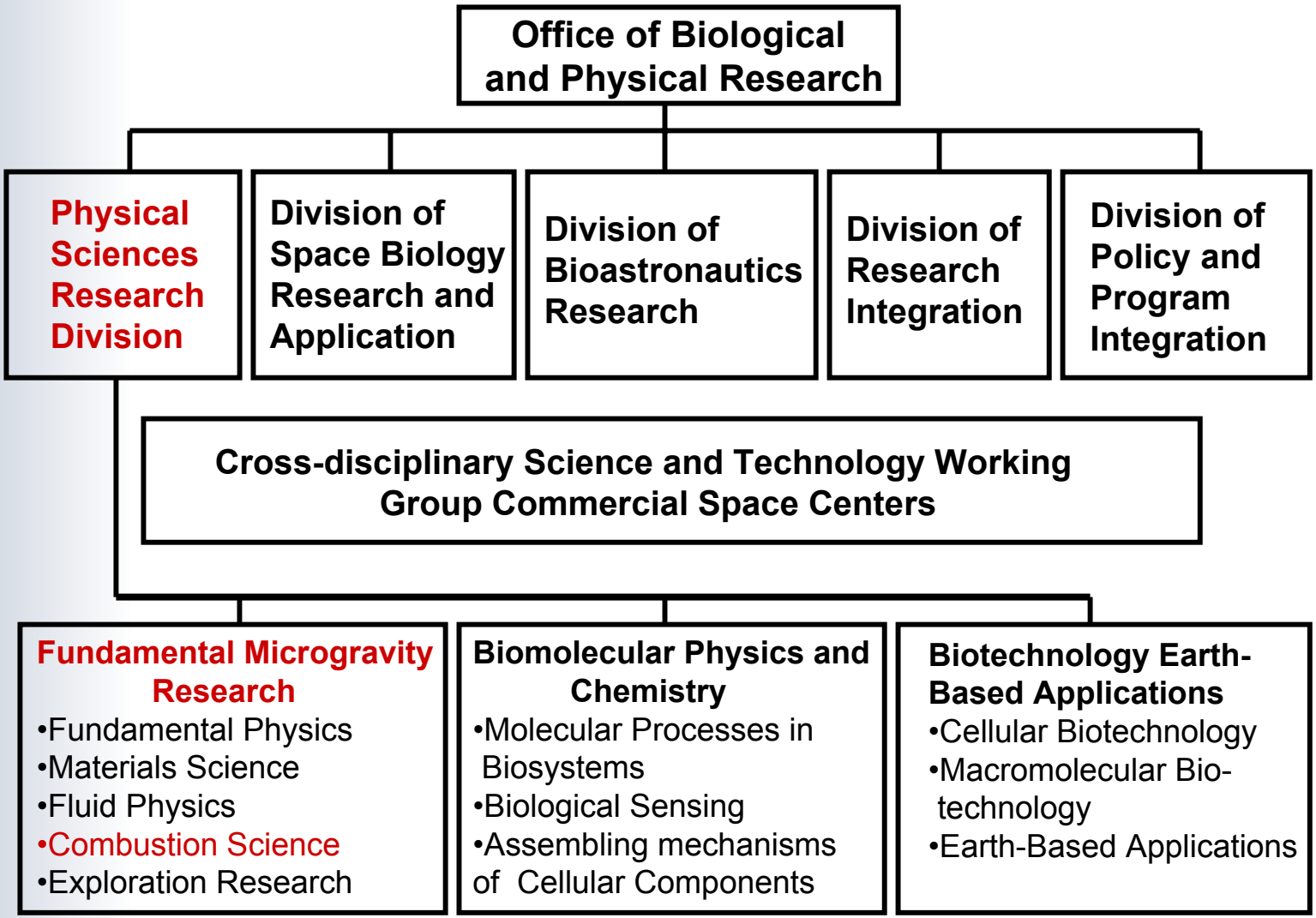
Code UG

Cleveland, OH
5/22/01

New Organization of OBPR Enterprise



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NASA

OBPR Enterprise Strategic Goals

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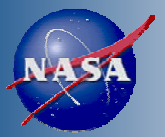
1. *Conduct research to enable safe and productive human habitation of space*
2. *Use the space environment as a laboratory to test fundamental principles of physics, chemistry, and biology*
3. Enable and promote commercial research in space
4. Use space research opportunities to improve academic achievement and the quality of life



Major Philosophical Changes in OBPR

- Aim For More Goal-Oriented Cross-Cutting Research (Less Stovepiping into the traditional disciplines)

- New NRA Structure Under Development
  - ✈ One Annual NRA for All of Physical Sciences
    - +Staggered Due Dates for Proposals in Each of the Traditional Disciplines
    - +Goal-Oriented Initiatives (Chef's Special)
  - ✈ Due to the fact that there will be an NRA evaluation each year for each discipline, the calls within each discipline may be more specific (limited) as to which subtopics will be considered within a given NRA (more definition by individual Enterprise Scientist as to which subtopics he wants to emphasize each year)

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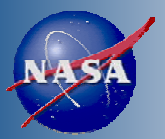
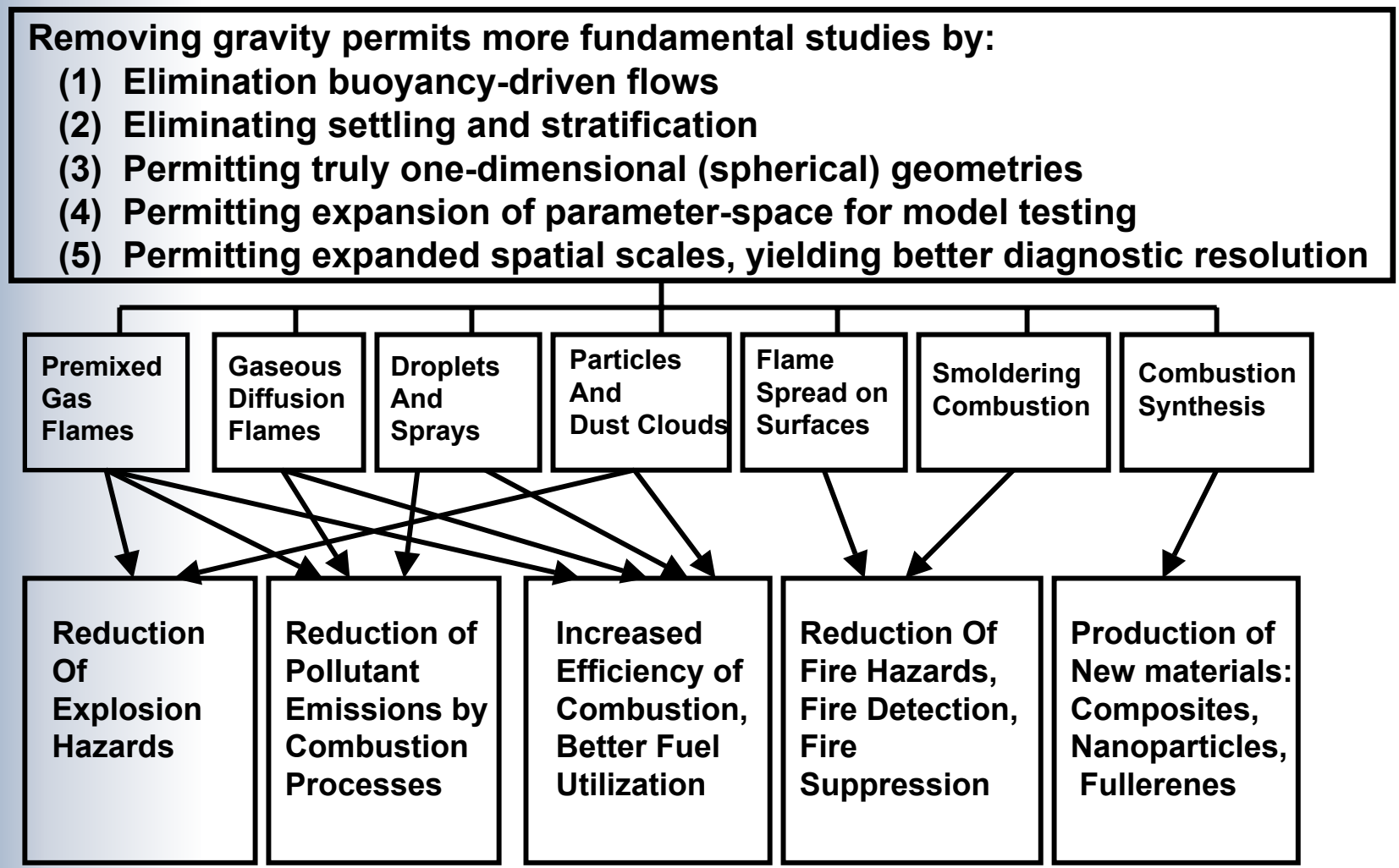


Flow Chart of Current Microgravity Combustion Program



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Long-term Goals of Microgravity Combustion Program

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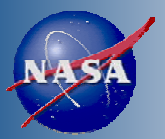
- Meld microgravity combustion space experiments with ground-based studies, using gravity as an added independent variable, to provide better mechanistic understanding and more rigorous testing of analytical models
- Utilize basic research to provide technological advances in various combustion processes/devices
- Create the understanding that will permit lessons learned in microgravity combustion experiments and modeling to be used in optimization of terrestrial combustion devices
- Provide quantum leaps in the areas of fire safety and economical minimization of combustion-generated pollution
- Provide the understanding that will permit efficient use of alternative fuels, which will be increasingly needed as we deplete oil and gas reserves
- Develop a better understanding of various combustion synthesis processes, opening the doors to production of novel tailored materials here on Earth as well as elsewhere



Sample Basic Science Issues to Be Addressed

- What are the interactions between turbulence and combustion?
- What controls soot formation, agglomeration, and oxidation?
- What mechanisms control flammability limits, detonations, instabilities?
- What factors control material ignitability, smolder, flame spread?
- Development of data bases for fundamental transport phenomena
- How do chemical kinetics and fluid dynamics couple in various scenarios?
- What controls boundary-layer interactions, acoustic-reaction feedbacks, and development of coherent structures in flames?
- How can the influences of thermophoresis, preferential diffusion, and electrical or magnetic field effects on combustion be understood and quantified?
- What are the quantitative effects of thermal radiation on various combustion processes?

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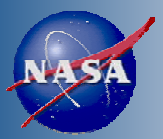

Sample Combustion Technology Goals

- Development of new flame stabilization/control technologies for burners enabling reliable ultra-lean premixed combustion
- Control flame-zone pollution in various burners through fundamental understanding of flame structures and pollutant formation mechanisms
- Development of miniaturized sensors and control algorithms for active control to improve thermal efficiency and decrease pollutant generation
- Development of improves strategies for fire prevention, detection, and suppression at reduced gravity
- Development of improved protection against large-scale fires through better understanding of material ignition and flamespread phenomena
- Reduction of mine and grain silo explosion hazards through improved understanding of fundamentals of these phenomena
- Development of ways of producing/utilizing alternate fuel/oxidizer combinations associated with extraterrestrial habitats
- Development of better understanding of combsynth processes, opening doors to production of novel tailored materials

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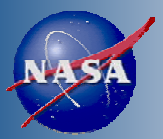
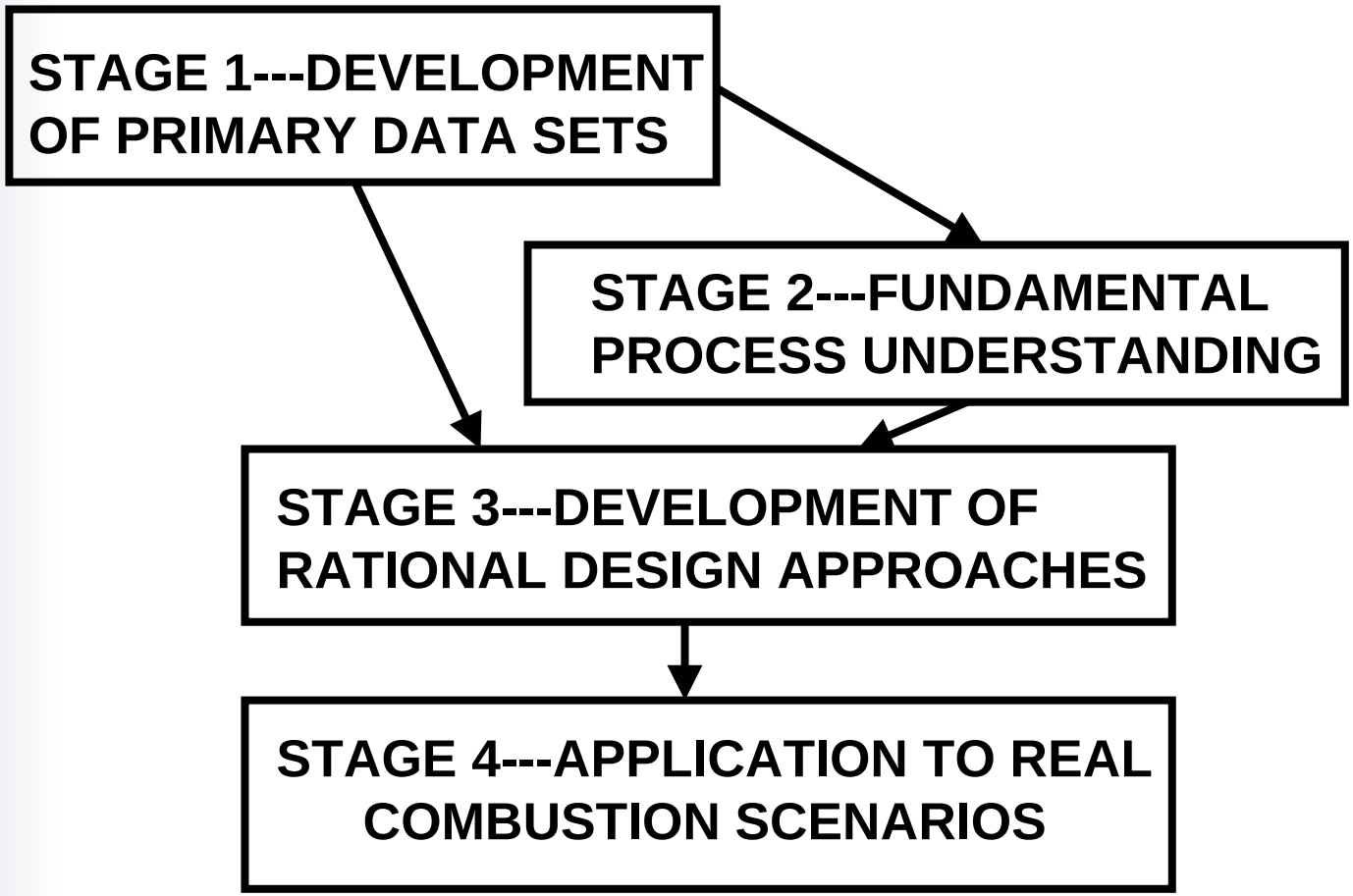


Microgravity Combustion Research Activity Stages



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STAGE 1---PRIMARY DATA SETS

- Equilibrium Thermodynamic Properties, Especially For Non-Ideal, Non-Dilute, and/or Multicomponent Mixtures
- Transcritical/Supercritical Properties
- Transport Properties (e.g., Mass and Thermal Diffusivities, Soret, and Dufour Effects)
- Reaction Rates/Mechanisms, Particularly at High Pressures where Strong Diffusive Effects can Confound the Issues for Non-isothermal Reactions at Normal Gravity Conditions

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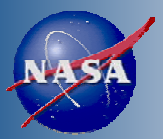

STAGE 2---FUNDAMENTALS OF UNIT PROCESSES AND THEIR INTERACTIONS

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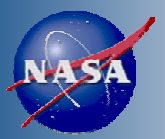
For this purpose, need data sets for such parameters as:

- **Autoignition Temperatures**
- **Flammability Limits**
- **Burning Rates and Thicknesses of Laminar Flames**
- **Markstein Lengths**
- **Extinction Stretch Rates**
- **Flame-front Instability Parameters**
- **Pollutant Emission Index Thresholds**



STAGE 3---DEVELOPMENT OF RATIONAL DESIGN APPROACHES

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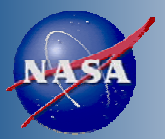
EXAMPLES:

- **Reduction of soot production from diffusion flames via burner design (e.g, splitting of oxygen and nitrogen from air with subsequent introduction of the nitrogen on the fuel side)**
- **Use of magnetic or electrical fields to “steer” reactants**
- **Design of flame zones to minimize pollutants**
- **Novel flame stabilization techniques**
- **Optimized design of materials synthesis processes**



STAGE 4---APPLICATION TO PRACTICAL COMBUSTION PROCESSES

Most of these will not be carried out by NASA but by others using NASA technology (spin-offs)

Examples:

- **Very Fuel-Lean Internal Combustion Engines**
- **Improved Fire Safety on Earth and is Space**
- **Development of New High-Value-Added Materials via Combustion Synthesis**
- **Exploration and development of Space Using In-Situ Resource Utilization and In-Situ Propellant Production**

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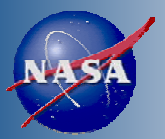

CURRENT THEMES OF COMBUSTION PROGRAM

Theme 1	Combustion of Liquid Fuels
Theme 2	Fire Safety/Surface Combustion
Theme 3	Premixed Gas Flames
Theme 4	Gaseous Diffusion Flames
Theme 5	Materials Synthesis Via Combustion
Theme 6	Combustion Research in Support of Exploration and Development of Space

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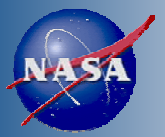

Subtopic Breakout of Current Program

Gaseous Flames
- Diffusion Flames
- Premixed Flames
- Partially Premixed Flames
- Triple Flames
- Flame-Vortex Interactions
- Kinetics
- Electrical Field Effects
- Magnetic Field Effects
- Flame Suppression
- Edge Flames

Droplets, Sprays, Particles, Dusts
- Single Droplets
- Droplet Arrays
- Sooting Droplets
- Sprays
- Particle Combustion
- Dust Clouds
- Bubble Combustion

Combustion Synthesis
- SHS
- Fullerene production via Flames
- Flame nanoparticle production
- Flame Agglomerate production
- Plasma Synthesis

Surface Combustion/Fire Safety
- Flame Spread
- Flammability Testing
- Flame Detection
- Extinguishment
- Smoldering
- Liquid Pool Combustion
- Secondary Fires

Miscellaneous
- G-Jitter Effects
- Propellant Combustion
- Cold Boundary Flames
- Diagnostics Development

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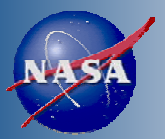

Possible Expansions of Program Activities

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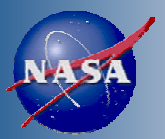
Potential New Research Areas

- CVD Processing
- CVI for Woven material Densification
- SuperCritical Water Oxidation
- In-situ Resource Utilization Power Cycles
- In-situ Chemical processing
- Thermal plasmas

Potential Initiatives (Clustered Programs)

- Active control of combustors
- Very Fuel-lean Combustors, Emphasis on H2
- Advanced Propulsion Systems for Interplanetary Travel
- Development/Use of Fullerenes and SWTs for H2 Storage

Potential Teaming with Other Agencies (DOE, NSF, NIST, AFOSR, ONR, ARO)



NASA Research Announcement (NRA)

- **Ground based research** **(About 18-20 awards anticipated)**
  - + Provides the intellectual underpinnings of the flight program
  - + Experimental and theoretical
  - + Well articulated microgravity relevance
    - Demonstration of the role of gravity; benefits to be accrued from conducting research in microgravity
    - Support for the microgravity combustion science program
  - + Funding for up to 4 years
  - + Average $100k/year

- **Flight experiments** **(About 0-3 awards anticipated)**
  - + High scientific and technical merit
  - + Well articulated need for a long duration, high quality microgravity environment
  - + Experimental and theoretical maturity to support a Science Concept Review within approximately two years
  - + Average $150k/year

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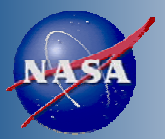

PROPOSAL EVALUATION CRITERIA

- **Is microgravity of fundamental importance to the proposed study?**
- **Do the issues addressed have the potential to close major gaps in the understanding of fundamentals of combustion processes?**
- **Is there potential for elucidation of previously unknown phenomena or interactions between phenomena?**
- **Is the project likely to have significant benefits/applications to ground-based as well as space-based operations involving combustion phenomena?**
- **Are the results likely to be broadly useful, leading to further theoretical or experimental studies?**
- **Can an additional project in the specific subarea being addressed be justified in terms of allocation of limited resources?**

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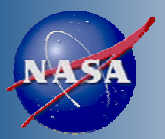

PROPOSAL EVALUATION CRITERIA

- Is the project technologically feasible, without requirements for substantial new technological advances?
- How well will this project stimulate research and education in the combustion area?
- How does the projected cost/benefit ratio compare with other projects competing for the same resources?
- What is the potential of this project in terms of stimulating future technological “spin-offs”?
- Are there strong well-defined linkages between the proposed research and goals of the Office of Biological and Physical Research?

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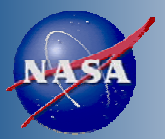

ADVICE FROM PAST REVIEWERS TO PROPOSERS

- Reviewers appreciate clear and concise writing.
  - Proof-read text and use clearly marked figures with appropriate captions.
- Reviewers will not "read between the lines."
  - While they may be familiar with your previous work, they will not assume that you are aware of important issues unless you indicate them explicitly.
  - What specific problems are to be investigated (experimentally or theoretically)? What is the working hypothesis?
- Appendices and supplementary material should be added judiciously.
  - Reviewers appreciate inclusion of publication reprints that report previous results that are key to the success of the proposed work. However, these should be kept to an absolute minimum.

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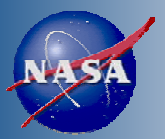

TENTATIVE 2001 NRA SCHEDULE

◆6th Int. Microgravity Comb. Conf.	May 22-24, 2001
◆CBD Announcement	Late October, 2001
◆NRA Release/Mailing	Late November, 2001
◆Letters-of-Intent Due	Mid January, 2002
◆Proposals Due	Late February, 2002
◆Review Panel Evaluations	May-June, 2002
◆Final Selections	Late August, 2002
◆Award/Declination Letters	Late September, 2002
◆Grant/Contract Placement	December, 2002

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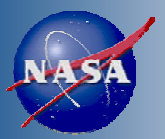

Documents/Websites of Interest

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Ongoing Research--Taskbook. Available on Web at:
http://peer1.idi.usra.edu/peer_review/taskbook/taskbook.html

NASA/Glenn Website------Includes Information on Facilities, Experiments, Educational Activities, Missions, Services, Etc. Available on Web at:
http://microgravity.grc.nasa.gov/combustion/
or,for more specific information aimed strictly at potential investigators,
http://microgravity.grc.nasa.gov/combustion/piinfo.htm

Microgravity Combustion Science:1995 Program Update----NASA TM 106858.
Available from Merrill King (202-358-0817) or Howard Ross (216-433-2562)

NASA/OBPR Research Opportunities Available on Web at:
http://research.hq.nasa.gov/code_u/open.cfm